63-4-2

AID Report P-63-80

6 June 1963

SOVIET LITERATURE ON LIFE SUPPORT SYSTEMS

A. BIOSCIENCES

AID Work Assignment No. 22

(Report No. 14 in this series)

Aerospace Information Division
Library of Congress

AID Report P-63-80 6 June 1963

SOVIET LITERATURE ON LIFE SUPPORT SYSTEMS A. BIOSCIENCES

AID Work Assignment No. 22

(Report No. 14 in this series)

Aerospace Information Division
Library of Congress

Foreword

This report was prepared in response to Work Assignment No. 22. It is the fourteenth in a series reviewing Soviet developments in life support systems. The report is based on materials made available at the Aerospace Information Division during January and February, 1963. Items are selected from Soviet open literature. The materials in this series are grouped according to the following topics:

PART A. BIOSCIENCES

I. Space medicine and biology
II. Space physiology
III. Perceptual physiology
IV. Space psychology
V. Space vehicle ecology
VI. Survival conditions

PART B. INSTRUMENTATION

Materials in this report deal with topics I and II.

AID Report P-63-80
Work Assignment No. 22(14)
6 June 1963

SOVIET LITERATURE ON LIFE SUPPORT SYSTEMS

PART A. BIOSCIENCES

TOPIC I. SPACE MEDICINE AND BIOLOGY

1) Poltavets, I. M., F. F. Sinitsyna, M. P. Filippov, and M. P. Kolyada. Preventive treatment of radiation sickness. IN THEIR: Ostryye radiatsionnyye porazheniya i ikh lecheniye [Acute radiation injuries and their treatment]. Kiyev, Gosmedizdat USSR, 1962. 70-72

A brief survey is given of preparations used for the protection of the animal organism against ionizing radiation. The preparations either inhibit radiochemical reactions in the organism or reduce its radiosensitivity.

Injection of organic sulfur-containing compounds, such as cysteine, glutathione, and β-mercaptoethylamine before irradiation produced a marked protective effect. The most effective and least toxic was β-mercaptoethylamine.

A mixture of adrenaline with acetylcholine when injected subcutaneously immediately before irradiation resulted in the survival of 35% of the test animals (controls, 100% lethal). The protective effect of the mixture was also manifested in a milder development of radiation sickness, accelerated restoration of the functions of the hematogenic system, and milder intestinal injuries. By comparison, the survival rate of animals administered cysteine and thiourea was 15 and 23%, respectively.

Sodium salicylate (500 mg/kg) injected intraperitoneally for a week prior to irradiation decreased the mortality of the test animals by 50%.

Narcotics (morphine) and barbiturates also possess a protective action against ionizing radiation.

The protein level is of great importance, since protein-deficiency increases the radiosensitivity of the animal. Some Soviet authors recommended incorporating protein hydrolyzates into the blood stream.

Artificial hyperglycemia induced in test animals before irradiation has been found to reduce their mortality from the effects of radiation on carbohydrate metabolism.

Table 1. Results of tests of the protective effect of AET in different animals

Kind of animal	AET dose, mg/kg	Mode of administration	Irradiation dose, r	Number of animals	Survived	Survival rate, %	T[1]	Mean life span of animals that died, days
Mice	500	Per os, 30 to 40 min before exposure	700	19	13	68	3.9	13
	600	same	700	20	8	40	1.6	16.7
	700	same	700	20	16	80	5.5	17.0
	Control	same	700	40	8	20	-	11.6
	500	same	750	80	32	40	7.3	14.3
	600	same	750	40	25	62.5	8.2	12.5
	700	same	750	56	24	43	6.5	13.2
	300	Intraperitoneally, 10 min before expsoure	650	77	33	43	7.6	14.2
	Control	-	750	158	-	0	-	6.2
Rats	400	Per os, 30 to 60 min before exposure	750	39	4	10	2.1	11.8
	500	same	750	20	-	0	-	12.7
	600	same	750	29	2	7	1.5	9.7
	200	Intraperitoneally, 10 min before exposure	750	38	5	13	2.4	10.4
	250	same	750	18	2	11	2.0	14.2
	Control	-	750	80	-	0	-	9.3
Dogs	200	Per os, 2 hr before exposure	350	4	1	-	1.1	15.7
	200 + treatment	Per os, 2 to 4 hr before exposure	350	8	2	-	1.3	18.1
	200 + treatment[2]	same	350	8	3	-	2.5	19.4
	Control	-	350	15	-	-	-	13.5

[1] T in survival rate was calculated by the alternative-variation method. The data are considered reliable with T > 3.

[2] In this series of experiments the doses of antibiotics and vitamins were doubled.

Administration of vitamin P (lemons for 30 days prior to irradiation) resulted in decreasing the mortality of the test animals by 10%. Antibiotics, particularly streptomycin, prevent the development of bacteriemia in animals. Some hormones, such as adenocorticotropic hormone and adrenal cortex extract, also protect against ionizing radiation. However, no completely reliable protective substance against ionizing radiation has been discovered.

2) Razorenova, V. A. Prevention of acute experimental radiation sickness by S-β-aminoethylisothiuronium (AET). Patologicheskaya fiziologiya i eksperimental'naya terapiya, no. 6, 1962, 49-54.

Total-body γ-irradiation (Co^{60}; dosage, 366-417 r/min) was administered in single doses to 510 white mice (700 r, LD_{80}; and 750 r, LD_{100}), 224 white rats (750 r, LD_{100}), and 35 mongrel dogs (350 r, LD_{100}). AET was administered to the rodents intraperitoneally or internally in the form of 2.5 to 5% aqueous solutions and to the dogs in the form of tablets in a piece of meat. The rodents were observed for 30 days, the dogs for 45 days after exposure.

AET injected internally (500, 600, or 700 mg/kg) 30 to 40 min before exposure (750 r) increased the survival rate of the mice by 40 to 62% and increased the life span of those that did not survive by 6 to 8 days as compared with the controls. When injected intraperitoneally (300 mg/kg) 10 min before exposure, AET increased by 8 days the life span of the mice that did not survive; 43% of the irradiated mice survived.

Administration of AET before irradiation had a beneficial effect on the course of radiation sickness in mice. In experiments with rats and dogs the administration of AET had only a weak protective effect and had no effect on the course of radiation sickness. A combination of AET with large doses of vitamins and antibiotics did not increase the survival rate of irradiated dogs.

The survival rate of mice with AET was twice as high as with cystamine hydrochloride (40 versus 20%), but with dogs AET was only about one-half as effective as mercamine (30 versus 67%).

The results of experiments with AET are shown in the table and figure.

Change in weight of irradiated mice (750 r)

1 - Controls; 2-4 - protected with AET: 2 - dose, 500 mg/kg; 3 - dose, 600 mg/kg; 4 - dose, 700 mg/kg.

3) Revis, V. A. Incorporation of methionine-S^{35} into the protein of bone marrow and spleen in acute radiation sickness and the effect of bone-marrow transplantation on this process. Radiobiologiya, v. 2, no. 6, 1962, 919-925.

Experiments were conducted with rabbits of the same breed 5 to 6 months old and weighing 2.7 to 3.0 kg in which acute radiation sickness was induced by total-body irradiation with 1100 r from an РУМ-3 apparatus (180 kv; 10 ma; filter, 0.5 mm Cu and 1.0 mm Al; distance, 40 cm). Methionine-S^{35} dissolved in 2 ml of physiological saline solution was injected subcutaneously into the spinal region (6000 pulses/min/g body weight) at different periods of radiation sickness. The animals were killed by air embolism 2 hr after injection of methionine-S^{35}, and 0.5-g samples were prepared of marrow from the thighbone and shinbone, of the spleen, and of

the skeletal muscles in the shank region. The weighed samples were processed, and the protein was freed of lipids and thoroughly washed to remove any traces of radioactivity. The washed and dried protein was pulverized and spread evenly over the target (10 mg/cm^2).

Two series of experiments were conducted. Thirty-two rabbits were employed in the first, as follows: 6 rabbits, 72 investigations (controls, no irradiation), incorporation of tagged methionine into protein of the bone marrow, spleen, and muscles; 3 rabbits (42 investigations), incorporation of tagged methionine into proteins of the same organs after exposure to 1100 r; 4 rabbits (52 investigations), incorporation of methionine 3 days after exposure; 5 rabbits (70 investigations), incorporation of methionine 6 days after exposure; 6 rabbits (72 investigations), incorporation of methionine 2 weeks after exposure; 5 rabbits (60 investigations), incorporation of methionine 1 month after exposure; 3 rabbits (36 investigations), incorporation of methionine 2 months after exposure (Table 1).

Table 1. Incorporation of methionine-S^{35} into protein from the bone marrow, spleen, and skeletal muscles of control and irradiated (1100 r) rabbits (in %)

Organ	Relative activity per gram protein						
	Control (without irradiation)	Period after exposure to 1100 r					
		Immediately after exposure	3 days	6 days	2 weeks	1 month	2 months
Bone marrow	4.5	8.5	9.8	3.3	1.1	2.6	10.6
Spleen	3.2	4.1	1.4	0.8	0.1	1.5	5.5
Muscle	0.8	0.8	0.1	0.07	0.02	0.3	0.6

In the second (24 rabbits) the incorporation of methionine-S^{35} was determined after the transplantation of 2.5 g of preserved bone marrow (from the thighbone and shinbone) 24 hrs after exposure. The breakdown was as follows: 3 rabbits (42 investigations), incorporation immediately after exposure to 1100 r (bone marrow transplanted, in these rabbits only, immediately after exposure); 4 rabbits (56 investigations), 3 days after exposure; 4 rabbits (56 investigations), 6 days after exposure; 4 rabbits (48 investigations), 2 weeks after exposure; 5 rabbits (60 investigations), 1 month after exposure; 4 rabbits (48 investigations), 2 months after exposure (Tables 2 and 3).

Table 2. Incorporation of methionine-S^{35} into protein from the bone marrow, spleen, and skeletal muscles of control and irradiated (1100 r) rabbits after transplantation of preserved bone marrow (in %)

Organ	Relative activity per gram protein						
	Control (without irradiation)	Period after exposure to 1100 r					
		Immediately after exposure	3 days	6 days	2 weeks	1 month	2 months
Bone marrow	4.5	8.1	6.6	3.5	3.9	4.4	7.3
Spleen	3.2	4.3	3.0	3.0	2.6	3.2	4.1
Muscle	0.8	0.7	0.4	0.3	0.1	0.6	0.9

Table 3. Level of incorporation of methionine-S^{35} into protein from the bone marrow, spleen, and skeletal muscles of irradiated (1100 r) rabbits as related to length of preservation of transplanted bone marrow

Period of preservation, days	Dose of transplanted bone marrow, g	Number of investigations	Relative activity per gram protein 2 weeks after exposure, %		
			Bone marrow	Spleen	Muscles
35-36	2.5	12	4.6	3.7	0.4
37-39	2.5	12	3.8	2.5	0.09
40	2.5	24	2.9	2.2	0.08

In series I a marked increase occurred in the rate of incorporation of methionine-S^{35} into protein of the bone marrow and spleen immediately after irradiation, while in the skeletal muscles the rate remained unchanged. It decreased markedly during the acute period of radiation sickness. The greatest decrease occurred 2 weeks after exposure (1.1, 0.1, and 0.02%, respectively, compared to 4.5, 3.2, and 0.8% in the controls). During the period of recovery the rate of methionine absorption in the bone marrow and spleen was gradually restored, exceeding the normal rate 2 months after exposure (10.6 and 5.5%), while the incorporation level in

the muscles still remained below that of the controls.

In series II the decrease in the rate of incorporation of methionine-S^{35} was less marked. The greatest decrease occurred in the bone marrow (3.5%) 6 days after exposure, in the spleen and muscles (2.6 and 0.1%, respectively) 2 weeks after exposure. The incorporation of methionine-S^{35} into proteins of bone marrow, spleen, and skeletal muscles was restored much more rapidly in irradiated rabbits after transplantation of bone marrow.

4) Zherebchenko, P. G., I. G. Krasnykh, Ye. I. Kuznets, N. N. Suvorov, V. S. Shashkov, and S. P. Yarmonenko. Radioprotective effect of the combined use of amines. Meditsinskaya radiologiya, no. 3, 1962, 67-72.

Experiments were conducted with pubescent mice (male and female) weighing 19 to 22 g subjected to total-body irradiation from an RUM-3 apparatus (180 kv; 15 ma; filters, 0.5 mm Cu and 1 mm Al; distance, 35 cm; dosage, 40 r/min). The preparations were dissolved in physiological saline solution immediately before the start of the experiment. Lyophilized mitochondria from the liver of white mice were used to study the action of monoamine oxidase on the drugs; tryptamine hydrochloride was used as standard substrate.

The combined use of mercamine and tryptamine (Table 1) in optimal doses (100 and 175 mg/kg) increased the survival rate of the animals to 85.5%, i.e., by 50 to 60% above that resulting from the use of these drugs individually. The results of experiments with these two drugs and hydrochloride are presented in Table 4. An increased effect was also obtained with the combined use of histamine with tryptamine and mercamine (Table 2). These drugs were just as effective when the animals were exposed to larger doses of radiation (800 r). Excessive doses of these drugs produced toxic effects, thus decreasing the protective effect. The combination of these drugs with some known radioprotective agent (e.g., AET with cystamine, mercamine, or tryptamine: Table 4) did not always produce a protective effect, probably as a result of the inhibition of the oxidative deamination of tryptamine by AET.

Experimental data on the combined use of AET with mercamine or cystamine indicate an effect similar to that produced by the three when used individually and argue for the similarity of their mechanisms. The differences in the capability of these drugs to increase the protective effect of tryptamine is probably due to their unequal effect on its deamination.

Table 1. Effect of mercamine and tryptamine used separately or in combination on the survival of mice irradiated with 700 r (intraperitoneal injection 5 to 10 min before irradiation)

Group	Preparation	Dose, mg/kg	Number of mice	Survived				Mean life span
				Number	%	±m	T[1]	
I	Control (no preparation)	-	60	1	1.6	-	-	11.7
II	Tryptamine HCl	100 75 50	30 30 30	7 5 3	23.3 16.6 10.0	7.8 5.3 5.6	3.03 2.6 1.4	16.8 12.4 12.8
III	Mercamine HBr	175 150 100	30 30 30	11 8 9	36.3 26.6 29.9	7.3 8.2 5.5	4.6 3.02 4.8	16.0 15.4 14.8
IV	Tryptamine HCl+ + mercamine HBr	100 175	35	30	85.5	6.02	$\frac{6.6}{5.1}$	16.2
	same	75 150	40	30	75	6.9	$\frac{6.3}{4.5}$	19.2
	same	50 100	40	21	52.5	8.0	$\frac{4.3}{2.3}$	18.7

[1] In the numerator, degree of reliability T with respect to tryptamine; in the denominator, with respect to mercamine.

Table 2. Protective effect of tryptamine, mercamine, and histamine injected separately or in combination into mice irradiated with 700 r (intraperitoneal injection 5 to 10 min before irradiation)

Group	Preparation	Dose, mg/kg	Number of mice	Survived	
				Number	%
I	Control (no preparation)	-	50	2	4.4
II	Histamine-2 HCl	350	69	20	29
III	Mercamine HCl	150	60	25	41.3
IV	Tryptamine HCl	100	69(7)	28	45.1
V	Histamine 2HCl + + mercamine HCl	262.5 112.5	89	60	67.5
	same	262.5 75	82(3)	54	68.3

Note: In parentheses, number of animals which died on the first day after exposure.

Table 3. Protective effect of mercamine and tryptamine in mice irradiated with 700 r in relation to the dose of preparation used

Preparation	Dose, mg/kg	Number of mice	Survived	
			Number	%
Mercamine hydrochloride	150	40	24	60.0
	225	20	10	50.0
Tryptamine hydrochloride	100	110	41	37.0
	150	49	11	22.4
	200	30	5	16.5
Control (no preparation)	-	30	1	3.3

Table 4. Effect of combined administration of AET with mercamine or tryptamine on the survival of mice irradiated with 700 r (intraperitoneal injection 5 to 10 min before irradiation)

Preparation	Dose mg/kg	Number of mice[1]	Survived				Mean life span
			Number	%	±m	T[2]	
Control (no preparation)	-	69	1	1.4	1.46	-	10.1
AET	150	89	55	61.8	5.14	11.3	19.5
Mercamine	150	40	24	60	7.85	7.3	16.8
Tryptamine	100	30	13	43.3	9.2	4.5	13.6
AET + mercamine	112.5 112.5	78	59	75.6	4.9	$\frac{1.94}{1.69}$	19.3
AET + tryptamine	112.5 75	70(26)	24	54.5	6.0	$\frac{0.92}{1.02}$	12.4
AET + tryptamine	75 50	20	6	30.0	10.3	$\frac{2.76}{0.96}$	17.6

[1] In parentheses, number of animals which died on the first day after exposure.
[2] In the numerator, degree of reliability T with respect to AET; in the denominator, with respect to mercamine or tryptamine.

TOPIC II. SPACE PHYSIOLOGY

1) Lagutina, N. Ya. The blood-coagulating system after transplantation of bone marrow in acute radiation sickness. Radiobiologiya, v. 2, no. 6, 1962, 855-858.

Experiments were conducted with 14 dogs of both sexes irradiated with a dose of LD_{100} (180 kv; 15 ma; filters, 0.5 mm Cu and 1 mm Al; distance, 70 cm; dosage, 12 r/min; total dose, 600 r). All the animals developed acute radiation sickness; 10 survived. Bone marrow obtained from dogs in amounts of 45 to 50 ml by puncture of the ilium, femur, tibia, and breastbone and stabilized with a 6% sodium citrate solution was transfused intravenously 2 or 8 to 10 days after exposure. The dogs were also given antibiotics. The clotting, recalcification, thrombin, and plasma and serum prothrombin time were measured, the free heparin, fibrin, proconvertin and proaccelerin contents were investigated, and a basic thromboplastin test was performed.

Injection of homologous bone marrow decreased the blood-clotting time and the content of free heparin, although an increase in the amount of heparin in the controls was observed, and caused a sharp drop in the number of thrombocytes in the peripheral blood, which did not rise until 20 to 25 days after exposure. Despite the low thrombocyte content, the decrease in prothrombin consumption in the treated dogs was insignificant. Thromboplastin was formed in 3 to 4 min; the prothrombin time was 20 to 30 sec (20% thromboplastin in the controls) (Figs. 1 and 2).

The change in thromboplastin formation with marked thrombopenia may be connected with the consumption of thrombocytic factors in case of the destruction of the transplanted bone marrow and the blood elements formed. The concentration of blood-clotting factors II, V, and VII did not change. Clot retraction decreased sharply and sometimes did not occur. It returned slowly to normal 20 to 25 days after treatment.

Of great importance in the prevention of hemorrhaging is the effect of bone-marrow transplantation on the decrease of heparin activity and on the activation of serotonine formation. It also prevents a decrease in thromboplastin formation.

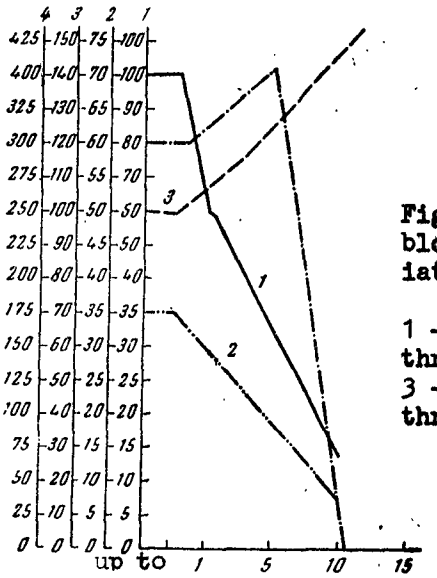

Fig. 1. Changes in indexes of blood-clotting system of irradiated untreated dog.

1 - thromboplastin content; 2 - prothrombin time of serum, in seconds; 3 - free heparin, %, 4 - number of thrombocytes, in thousands.

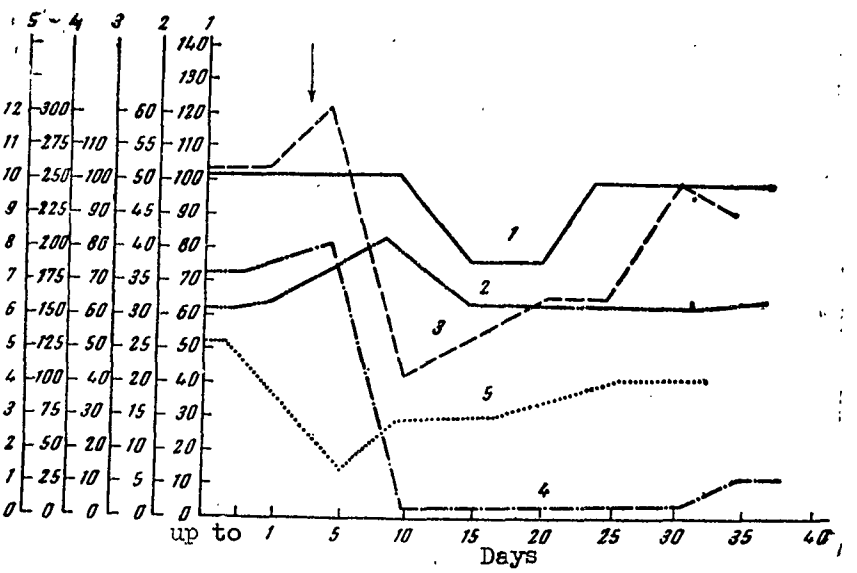

Fig. 2. Changes in indexes of blood-clotting system of irradiated dog after bone-marrow transfusion

Designations same as in Fig. 1; 5 - blood-clotting time in minutes. Arrow indicates time of transfusion.

2) Lozina-Lozinskiy, L. K. Tolerance of insects to extremely low temperatures. IN: Akademya nauk SSSR. Doklady, v. 147, no. 5, 1962, 1247-1249.

Corn borer caterpillars (in diapause) kept at 0 to -4°C for 3 to 4 weeks showed a marked increase in tolerance to low temperatures. When cooled first to -30°C and then to -78°C, 100% survived after thawing; when cooled to -30°C and then to -196°C, 60 to 70% survived. Caterpillars not subjected to a precooling period of -30°C survived at -78°C but died at -183°C and -196°C. Without a precooling period at approximately 0°C only a small number of caterpillars survived at -78°C and only individual caterpillars reacted to an electrical stimulus when exposed to -196°C. Temperatures below 0°C did not develop tolerance to extremely low temperatures (Table 1).

Table 1. Effect of conditions before and after cooling on the tolerance of caterpillars to -78°C

Number of experiment	Date of experiment	Number of caterpillars	Holding temperature, °C		Reaction after thawing	Survival and development
			Before cooling	After cooling		
23	30 Nov 61	20	22	22	5% react to electric current (e.c.)	Died after 1 day
22	"	20	10	22	25% mobile, 15% react to e.c.	Survived 3 to 34 days
24	"	21	4	22	76.2% mobile, 14.3% react to e.c.	Survived 5 to 55 days
21a	"	20	0	to 28 Dec, 0; after 28 Dec, 22	100% mobile	40% pupated, 30% butterflies
21b	"	10	-2	"	100% mobile	30% pupated, 20% butterflies
21c	"	10	-2	22	100% mobile	Survived 2 to 23 days

In two experiments 11 out of 30 caterpillars went through their usual cycle, i.e., chrysalis, butterfly, and oviposition. The speed of cooling and the sequence of temperatures were found to be of great importance to the development of tolerance in the caterpillars (Table 2). It was observed that a temperature of -50°C had a more

Table 2. Tolerance of caterpillars to extremely low temperatures at various sequence, speed, and duration of cooling. Holding temperature, 4°C

Number of experiment	Date of experiment	Number of caterpillars	Cooling sequence	Reaction after thawing	Life span, days
32	18 Dec 61	20	35 min, - 30° 2 days, - 78° 120 min, -196°	55% mobile, 15% react to e.c.	4 -44
34	23 Dec 61	"	60 min, - 30° 60 min, - 78° 120 min, -196°	55% mobile, 35% react to e.c.	6.7-35
33	"	"	30 min, - 30° 30 min, - 50° 60 min, -196° 120 min, -196°	60% mobile, 10% react to e.c.	7 -35
35	"	"	60 min, - 50° 60 min, - 78° 120 min, -196°	0% mobile, 5% react to e.c.	4 -6
37	27 Dec 61	"	60 min, - 50°	0% mobile, 15% to 25% react to e.c.	<10
38	28 Dec 61	"	60 min, - 78°	58.3% mobile, 33.3% react to e.c.	5 -10

harmful effect than -78°C or even -196°C. The reason for this phenomenon has not been determined as yet, but it is surmised that it is associated with the nature of crystallization of water in the tissues of the caterpillars.

The duration of holding at a given temperature did not markedly affect survival. At periods ranging from 30 min to 5 days 100% survived after thawing; after a period of 25 days, 79.2% survived.

The tolerance of the insects to extremely low temperatures indicates that complex organisms can be kept in a condition of anabiosis, although there are dangerous temperature zones such as -50°C, which the organism must "slip through" very rapidly. The mechanism of adaptation is under further investigation.

3) Savitskiy, I. V., A. Ya. Rozanov, and L. Ye. Pozdnyakova. Effect of x-irradiation on phosphorylation of thiamine. Voprosy meditsinskoy khimii, v. 8, no. 6, 1962, 592-598.

Experiments were conducted with 68 male white mice weighing 18 to 24 g. Radiation sickness was induced in 48 mice by x-irradiation with 600 r (180 kv; 10 ma; filters, 0.5 mm Cu and 1.0 mm Al; focal distance, 40 cm; dosage, 26.3 r/min). The remaining twenty mice served as controls. Thiamine-S^{35} freed of radioactive admixtures was injected subcutaneously in a dose of 100 µg per animal. The mice were decapitated 1 hr after the vitamin was administered. The liver and small intestine (emptied) were quickly removed and frozen, and the content of free and total thiamine-S^{35} was determined.

Chromatographic analyses showed that tagged thiamine in the trichloroacetic liver extracts occurred mainly in the form of its phosphoric esters (thiamine triphosphate, thiamine pyrophosphate, and thiamine monophosphate) and partly as free thiamine-S^{35}. Very small quantities of S^{35}-thiamine disulfide and S^{35}-thiochrome were also found. The rate of accumulation of tagged vitamin B_1 in the liver and small intestine was determined by calculating the relative activity (Table 1).

X-irradiation caused a decrease in the organism's ability to utilize thiamine, as manifested by a one-third decrease in the accumulation of thiamine-S^{35} in the liver and small intestine of the irradiated animals, and was accompanied by inhibition of thiamine phosphorylation (76 to 78% as compared to 90% in the controls). These effects were observed 2 days after exposure and were not fully eliminated, even by the 19th day. Inhibition of phosphorylation in the small intestine was most pronounced 3 to 7 days after exposure; in the liver, 5 to 7 days after exposure.

The early inhibition of thiamine phosphorylation indicates high sensitivity of the thiamine-kinase system to ionizing radiation. It is probable that inhibition of the thiamine-kinase reaction is a factor in the decreased rate of phosphorylation, decreased ATP level in animal tissues, and disturbance in protein metabolism after x-irradiation.

Table 1. Accumulation of tagged vitamin B_1 in the organs 60 min after injection of thiamine-S^{35} (5 mg/kg) into white mice previously exposed to 600 r

Relative activity[1]						
Irradiated mice				Control mice		
Number of mouse	Day after exposure	Liver	Small intestine	Number of mouse	Liver	Small intestine
1	2d	136	144	1	188	216
2	2d	176	136	2	248	345
3	2d	243	199	3	224	254
4	2d	180	161	4	206	217
5	2d	190	174	5	238	231
6	2d	149	113	6	225	229
7	2d	140	127	-	(221)	(248)
8	2d	130	127	-	-	-
		(167)	(147)			
9	3d	146	146	7	142	184
10	3d	116	184	8	258	284
11	3d	150	121	9	283	254
12	3d	154	104	10	235	232
13	3d	130	140	-	(229)	(238)
14	3d	176	152	-	-	-
		(145)	(141)			
15	5th	159	119	11	284	172
16	5th	216	152	12	197	203
17	5th	136	129	13	142	175
18	5th	150	124	14	148	168
19	5th	150	204	-	(193)	(179)
20	5th	175	105	-	-	-
		(164)	(139)			
21	7th	133	137	15	235	195
22	7th	130	137	16	277	288
23	7th	117	130	17	232	222
24	7th	139	144	18	252	262
25	7th	145	149	-	(249)	(241)
		(133)	(139)			
26	19th	138	137	19	276	278
27	19th	149	157	20	225	202
28	19th	157	163	-	(250)	(240)
29	19th	151	165			
		(149)	(155)			
n = 29		M = 151 $\sigma = \pm 26.5$ m = 4.9 T = 7.7	M = 144 $\sigma = \pm 24.4$ m = 4.5 T = 8.5	n = 20	M = 236 $\sigma = \pm 44.3$ m = 9.8	M = 237 $\sigma = \pm 45.0$ m = 10.0

n - number of experiments; M - arithmetical mean; σ - standard deviation
σ - mean deviation of arithmetical mean ($m = \sigma / \sqrt{n}$); T - reliability index of the difference of the two arithmetical means: $T = (M_2 - M_1) / \sqrt{m_1^2 + m_2^2}$

[1] Parentheses indicate mean values

Table 2. Phosphorylation of thiamine-S^{35} in the organs 60 min after its injection (5 mg/kg) into white mice previously exposed to 600 r (%)

Irradiated mice						Control mice				
		Liver		Small intestine			Liver		Small intestine	
Number of mouse	Day after exposure	Free thiamine	Thiamine phosphates	Free thiamine	Thiamine phosphates	Number of mouse	Free thiamine	Thiamine phosphates	Free thiamine	Thiamine phosphates
1	2d	16.6	83.4	17.0	83.0	1	14.1	85.9	12.9	87.1
2	2d	18.8	81.2	18.9	80.1	2	6.1	93.9	8.2	91.8
3	2d	16.8	83.2	18.6	81.4	3	6.6	93.4	8.9	91.1
4	2d	20.3	79.7	20.7	79.3	4	8.7	91.3	8.5	91.5
5	2d	16.8	83.2	19.8	80.2	5	6.6	93.4	7.1	92.9
6	2d	21.0	79.0	29.1	70.9	6	7.6	92.4	6.5	93.5
7	2d	21.2	78.8	24.8	75.2	-	(8.3)	(91.7)	(8.7)	(91)
8	2d	18.8	81.2	17.7	82.3	-	-	-	-	-
		(18.8)	(81.2)	(20.8)	(79)					
9	3d	13.8	86.2	22.1	77.9	7	13.2	86.8	12.4	87.6
10	3d	16.8	83.2	17.1	82.9	8	7.4	92.6	7.0	93.0
11	3d	15.6	84.4	36.1	63.9	9	9.3	90.7	9.7	90.3
12	3d	23.8	76.2	35.2	64.8	10	7.5	92.5	8.2	91.8
13	3d	30.4	69.6	21.4	78.6	-	(9.3)	(90.7)	(9.3)	(90.7)
14	3d	25.6	74.4	16.0	84.0	-	-	-	-	-
		(21.0)	(79.0)	(24.6)	(75.4)					
15	5th	25.0	75.0	29.4	70.6	11	8.9	91.1	7.7	92.3
16	5th	23.2	76.8	18.2	81.8	12	6.3	93.7	6.1	93.9
17	5th	19.6	80.4	21.3	78.7	13	5.1	94.9	7.0	93.0
18	5th	21.4	78.6	19.2	80.8	14	10.7	89.3	8.4	91.6
19	5th	25.0	75.0	11.2	88.8	-	(7.7)	(92.3)	(7.3)	(92)
20	5th	32.4	67.6	29.3	70.7	-	-	-	-	-
		(24.4)	(75.6)	(21.6)	(78.4)					
21	7th	20.4	79.6	18.9	81.1	15	7.8	92.1	7.8	92.2
22	7th	26.8	73.2	22.8	77.2	16	9.5	90.5	7.6	92.3
23	7th	32.6	67.4	25.6	74.4	17	10.1	89.9	8.9	91.1
24	7th	31.6	68.4	29.2	70.8	18	6.7	93.3	7.2	92.8
25	7th	25.5	74.5	23.5	76.5	-	(8.5)	(91.5)	(7.9)	(92)
26	19th	24.0	76.0	20.2	79.8	19	5.7	94.3	5.0	95.0
27	19th	17.7	82.3	15.9	84.1	20	10.8	89.2	10.4	89.6
28	19th	16.6	84.0	15.0	85.0	-	(8.2)	(91)	(7.7)	(92)
29	19th	15.6	84.4	13.0	87.0	-	-	-	-	-
		(18.4)	(81.6)	(16.0)	(82.0)					
n = 29		M = 24.0% σ = ±5.7 m = 1.0 t = 13.9		M = 21.8% σ = ±6.0 m = 1.1 T = 11.7		n = 20	M = 8.4% σ = ± 2.3 m = 0.5		M = 8.2 σ = ±1.9 m = 0.4	

4) Shepshelevich, I. L., and L. S. Rogacheva. Distribution of radioactive vitamin B_{12} in the plasma and organs of rats with acute radiation sickness. Radiobiologiya, v. 2, no. 6, 1962, 843-846.

Experiments were conducted with 53 Wistar and Capuchin (Kapyushonnyye) strain rats weighing 200 to 350 g. Twelve rats were exposed to 500 r and nine to 700 r (180 kv; 10 ma; filters, 0.5 mm Cu + 1 mm Al; distance, 44 cm; dosage, 20 r/min); 32 rats served as controls. Radioactive vitamin B_{12} (tagged with Co^{60}) was injected intramuscularly in a single dose of 0.5 to 0.6 μcu (13 to 16 γ of vitamin B_{12}) 24 hrs after exposure. The specific activity of the preparations was 36.6 to 36.9 μcu/mg.

The animals in which the intermediate metabolism of B_{12} - Co^{60} was studied were divided into seven groups. The rats were decapitated 2, 4, 6, 8, 10, and 14 days after exposure, and the radioactivity in the plasma and organs was measured (see table). Injection of radioactive B_{12} into 15 healthy rats slightly stimulated blood formation and did not produce toxic side-effects.

Two to four days after exposure to 500 r the greatest amount of vitamin was found in the kidneys, followed by the heart and spleen, and finally by the liver. After 8 to 14 days the concentration of tagged B_{12} in these organs was almost identical. There was no essential difference between the distribution of vitamin B_{12} in the blood and organs of rats exposed to 700 r and that in the norm. Tagged B_{12} injected intramuscularly into irradiated and healthy animals in mean doses of 0.07 γ/g was absorbed in very small amounts (~ 3%) on the 14th day. Large amounts of the injected vitamin (50 to 80%) were found in the excreta. No disturbances in the intermediate metabolism of the vitamin occurred in rats with mild and moderate degrees of acute radiation sickness.

Change in content of B_{12}-Co^{60} (% of dose injected) in plasma and organs of irradiated and control rats (mean data)

Group of animals	Days after exposure	Plasma		Liver		Spleen	
		In entire volume	In 1 ml	In entire organ	In 0.5 g	In entire organ	In 0.5 g
1 Irradiated, 500 r	2	0.140±0.02	0.015±0.003	0.725±0.03	0.033±0.001	0.140±0.012	0.090±0.01
Control	-	0.120±0.02	0.013±0.001	0.543±0.02	0.023±0.001	0.21 ±0.016	0.130±0.03
2 Irradiated, 500 r	4	0.071±0.01	0.007±0.002	1.051±0.06	0.042±0.002	0.140±0.01	0.102±0.01
Control	-	0.056±0.01	0.007±0.002	0.921±0.02	0.033±0.005	0.151±0.03	0.101±0.05
3 Irradiated, 500 r	8	0.050±0.01	0.006±0.001	1.381±0.1	0.075±0.01	0.132±0.01	0.110±0.01
Control	-	0.050±0.007	0.005±0.001	1.292±0.1	0.065±0.002	0.141±0.04	0.130±0.03
4 Irradiated, 500 r	14	0.041±0.01	0.004±0.001	1.213±0.25	0.075±0.01	0.160±0.01	0.061±0.004
Control	-	0.035	0.0031	1.41	0.090	0.15	0.08
5 Irradiated, 700 r*	2	0.058±0.003	0.014	0.560±0.06	0.035±0.002	0.060±0.004	0.07 ±0.007
Control*	-	0.063±0.002	0.014	0.450±0.04	0.030±0.001	0.050±0.007	0.065±0.005
6 Irradiated, 700 r*	6	0.028±0.004	0.01±0.0003	0.740±0.05	0.045±0.005	0.054±0.004	0.057±0.005
Control*	-	0.030	0.01	0.89	0.054	0.06	0.06
7 Irradiated, 700 r*	10	0.010±0.003	0.003±0.001	0.910±0.01	0.065±0.001	0.046±0.01	0.045±0.006
Control*	-	0.026±0.004	0.004±0.001	0.76 ±0.03	0.054±0.003	0.060±0.01	0.05

*Degrees of radioactivity in organs of this series of experiments are slightly below corresponding data obtained with a dose of 500 r, since the B_{12}-Co^{60} injected had a lower specific activity.

(Cont.)

(Cont.)

	Group of animals	Days after exposure	Thigh and Leg Bones		Heart		Kidneys	
			In both bones	In 0.5 g	In entire organ	In 0.5 g	In both kidneys	In 0.5 g
1	Irradiated, 500 r	2	0.050±0.004	0.014±0.001	0.13±0.01	0.055±0.002	5.612±0.5	1.400±0.5
	Control	-	0.040±0.007	0.012±0.003	0.09±0.001	0.045±0.005	4.320±0.28	1.050±0.025
2	Irradiated, 500 r	4	0.043±0.004	0.015±0.001	0.142±0.024	0.091±0.007	5.325±0.52	1.220±0.005
	Control	-	0.032±0.005	0.012±0.002	0.095±0.01	0.072	4.790±0.30	1.400±0.012
3	Irradiated, 500 r	8	0.043±0.01	0.015±0.003	0.131±0.01	0.085±0.01	3.010±0.20	0.810±0.1
	Control	-	0.042±0.016	0.011±0.002	0.132±0.02	0.069±0.01	2.212±0.35	0.610±0.1
4	Irradiated, 500 r	14	0.032±0.004	0.005	0.161±0.03	0.091±0.02	1.610±0.13	0.48±0.02
	Control	-	0.004	0.007	0.180	0.140	1.95	0.60
5	Irradiated, 700 r*	2	0.023±0.004	0.006±0.002	0.060±0.007	0.04±0.005	3.600±0.05	1.120±0.05
	Control*	-	0.027±0.002	0.009	0.070±0.003	0.035±0.001	3.800±0.02	1.020±0.005
6	Irradiated, 700 r*	6	0.025±0.003	0.006±0.004	0.061±0.06	0.032±0.001	2.400±0.25	0.790±0.14
	Control*	-	0.03	0.009	0.08	0.04	2.200	0.68
7	Irradiated, 700 r*	10	0.022±0.001	0.007±0.001	0.100±0.01	0.061±0.006	1.800±0.36	0.580±0.09
	Control*	-	0.024±0.002	0.006±0.002	0.100±0.01	0.080±0.01	2.300±0.2	0.690±0.08

5) Vladimirov, V. G. Effect of cystamine on oxidative phosphorylation in the spleen of irradiated white rats. Byulleten' eksperimental'noy biologii i meditsiny, no. 11, 1962, 55-57.

Experiments were conducted with white male rats weighing 90 to 150 g exposed to total-body irradiation with 600 r (180 kv; 15 ma; dosage, 9.2 and 11.2 r/min; filters, 0.5 mm Cu and 1 mm Al; focal distance, 70 cm). The test rats were decapitated 1, 2, 3, 6, and 9 days after exposure. The animals in which the effect of cystamine on oxidative phosphorylation was to be studied (on the 3rd, 6th, and 9th days after exposure) received immediately before exposure an intraperitoneal injection of a 1% neutralized solution of cystamine hydrochloride, calculated on the basis of 75 mg per kg body weight. Splenic tissue was homogenized in a solution of saccharose (0.25 M) to which versene (0.01 M) and NaF (0.1 M) were added. The tissue and saccharose solution were used in a ratio of 1:3. The incubation medium consisted of potassium phosphate buffer (0.006 M), triethanolamine buffer (0.016 M), glucose (0.02 M), succinic acid (0.012 M), $MgCl_2$ (0.006 M), ATP (0.001 M), and crystalline hexokinase (1 mg per ml of the medium). The pH of the mixture was 7.6. The incubation period was 20 min at 36°C. The rates of oxidation and phosphorylation were determined by the loss of oxygen and inorganic phosphate (Table 1).

Cystamine caused an increase in the amount of inorganic phosphate in the splenic tissue on the 3d day after exposure to almost twice the amount in the irradiated control animals (Table 2). However, owing to a simultaneous 64% increase in oxygen consumption, the P:O coefficient changed only slightly. Increase in the level of phosphorylation in the spleen of irradiated rats was observed on the 6th and 9th days.

The experimental results obtained show that administration of cystamine before exposure to x-irradiation moderates the changes in oxidative phosphorylation occurring in the spleen of irradiated rats.

Table 1. Changes in oxidative phosphorylation in splenic homogenates from rats exposed to total-body irradiation with 600 r

Day after exposure	No. of rats	No. of analyses	Amount of bound phosphorus, μg		Amount of oxygen consumed (μl)		Coefficient P:O	
			M ± m	P	M ± m	P	M ± m	P
before exposure	26	13	206±11.7	-	73±6	-	1.05±0.05	-
1st	20	10	188±10.6	Unreliable	76±7	Unreliable	0.95±0.09	Unreliable
2d	27	10	131±12.8	< 0.001	94±8	< 0.02	0.52±0.07	< 0.001
3d	34	10	69±9.9	< 0.001	64±5	Unreliable	0.40±0.05	< 0.001
6th	24	9	204±21	Unreliable	82±6	Unreliable	0.96±0.17	Unreliable
9th	18	9	180±9.9	Unreliable	98±9.1	< 0.05	0.67±0.04	< 0.001

* M - arithmetical mean; P - probability of variations.

Table 2. Effect of cystamine on oxidative phosphorylation in the spleen of irradiated rats

Day after exposure	No. of rats	No. of analyses	Amount of bound phosphorus, μg			Amount of oxygen consumed			Coefficient P:O		
			M ± m	%	P	M ± m	%	P	M ± m	%	P
3d	24	10	136±12.1	199	<0.001	105±5.4	164	<0.001	0.47±0.04	117	Unreliable
6th	16	10	254±16.6	124	Unreliable	92±6.2	111	Unreliable	1.04±0.09	108	Unreliable
9th	14	9	228±9.8	126	<0.01	102±8.4	104	Unreliable	0.85±0.08	127	<0.001

* Percentages are given in relation to amount in irradiated control rats.

BIBLIOGRAPHY

1. Lagutina, N. Ya. The blood-coagulating system after transplantation of bone marrow in acute radiation sickness. Radiobiologiya, v. 2, no. 6, 1962, 855-858.

2. Lozina-Lozinskiy, L. K. Tolerance of insects to extremely low temperatures. IN: Akademiya nauk SSSR. Doklady, v. 147, no. 5, 1962, 1247-1249.

3. Poltavets, I. M., F. F. Sinitsyna, M. P. Filippov, and M. P. Kolyada. Preventive treatment of radiation sickness. IN THEIR: Ostryye radiatsionnyye porazheniya i ikh lecheniye [Acute radiation injuries and their treatment]. Kiyev, Gosmedizdat USSR, 1962. 70-72.

4. Razorenova, V. A. Prevention of acute experimental radiation sickness by S-β-aminoethylisothiuronium (AET). Patologicheskaya fiziologiya i eksperimental'naya terapiya, no. 6, 49-54.

5. Revis, V. A. Incorporation of methionine-S^{35} into the protein of bone marrow and spleen in acute radiation sickness and the effect of bone-marrow transplantation on this process. Radiobiologiya, v. 2, no. 6, 1962, 919-925.

6. Savitskiy, I. V., A. Ya. Rozanov, and L. Ye. Pozdnyakova. Effect of x-irradiation on phosphorylation of thiamine. Voprosy meditsinskoy khimii, v. 8, no. 6, 1962, 592-598.

7. Shepshelevich, L. L., and L. S. Rogacheva. Distribution of radioactive vitamin B_{12} in the plasma and organs of rats with acute radiation sickness. Radiobiologiya, v. 2, no. 6, 1962, 843-846.

8. Vladimirov, V. G. Effect of cystamine on oxidative phosphorylation in the spleen of irradiated white rats. Byulleten' eksperimental'noy biologii i meditsiny, no. 11, 1962, 55-57.

9. Zherebchenko, P. G., I. G. Krasnykh, Ye. I. Kuznets, N. N. Suvorov, V. S. Shashkov, and S. P. Yarmonenko. Radioprotective effect of the combined use of amines. Meditsinskaya radiologiya, no. 3, 1962, 67-72.